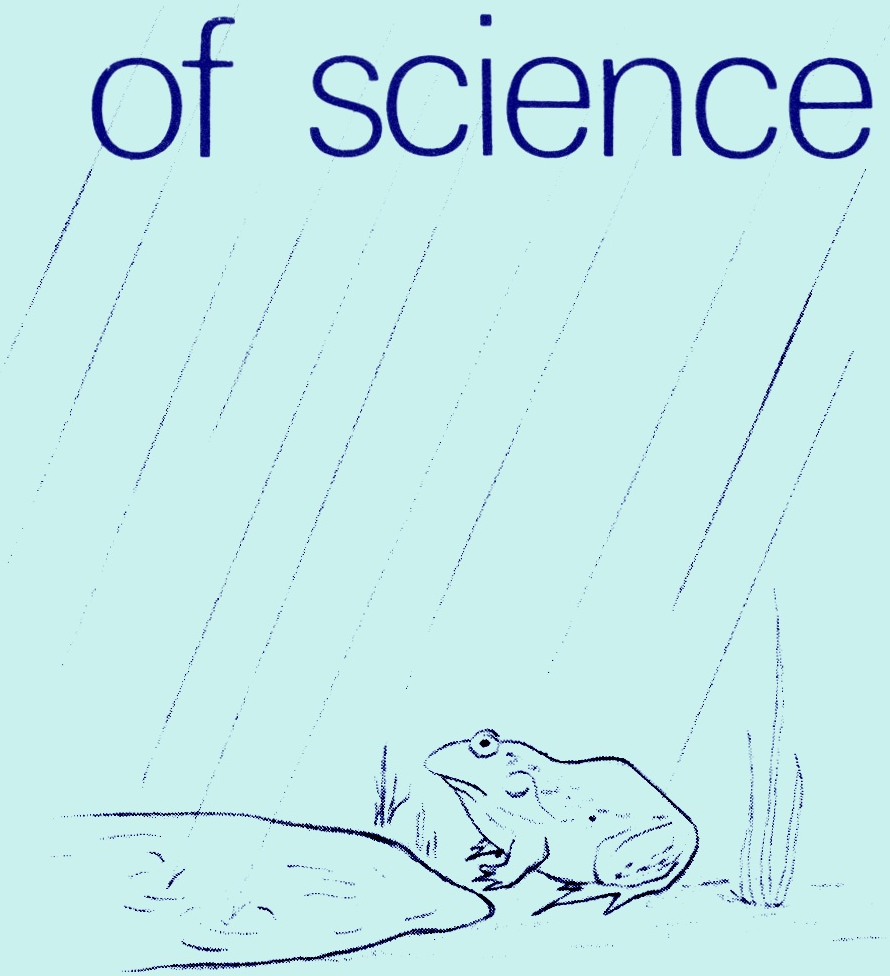
THINGS of science



HUMIDITY

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HUMIDITY

A person's physical comfort in everyday life depends upon many environmental factors, one of the most important of these being humidity, or the amount of water vapor in the air.

Water is evaporating from the earth continuously, from the oceans, trees and plants, and the soil itself. Thus the atmosphere contains a variable amount of water vapor at all times. This moisture in the air is known as atmospheric humidity.

If there is too much water vapor in the air, a person is uncomfortable because the perspiration from his body does not evaporate quickly enough to cool him off. In summer, people may complain about the weather being damp or muggy. You no doubt have often heard the expression, "it isn't the heat, it's the humidity."

Wash on the lines takes much longer to dry in hot humid weather than in cold dry weather, even though the temperature is higher because evaporation is so much slower in damp weather.

There are a number of simple devices that are used to indicate whether the air is damp or dry and to measure the extent of the humidity. With the materials in this unit you will be able to apply some

of these methods and check the humidity in your immediate environment.

First identify your specimens.

THERMOMETERS—Two thermometers for building a wet-and-dry-bulb hygrometer. Celsius readings are at the left and Fahrenheit at the right.

WICK—Four-inch length of cotton wick for the wet bulb.

PLASTIC STRAW—Four inches long; for making a hair hygrometer.

COBALT CHLORIDE—Crystals that turn blue when dry and pink when damp.

HUMIDITY TABLE—For calculating relative humidity.

HYGROMETER

A hygrometer is an instrument for measuring the relative humidity of the surrounding atmosphere.

The relative humidity is defined as the ratio of the amount of water vapor actually present in the air at a certain temperature to the amount it would contain at the same temperature if saturated, and is usually expressed in percent.

Experiment 1. One common instrument for observing the humidity is the wet-and-dry-bulb hygrometer.

In such a device, two thermometers are used. One is wrapped in a damp cloth

and the other is left dry. The dry bulb thermometer gives the temperature of the surrounding air, while the wet bulb gives a reading which results when the water evaporates from the damp cloth and is lower than that of the dry bulb.

The evaporating water cools the wet bulb and lowers the temperature. If the air is humid, evaporation is slow and the wet bulb is cooled only slightly. Therefore there will be only a slight difference in the temperatures of the two bulbs. But if the air is dry, evaporation is rapid and the cooling effect greater and thus the difference between the temperatures is larger.

Tables have been devised by the U. S. Weather Bureau from which relative humidity values can be obtained if the difference in temperatures betwen the dry bulb, t, and the wet bulb, t′ is known at a given temperature.

The table enclosed shows these values in Fahrenheit.

Let us construct a wet-and-dry-bulb hygrometer, also known as a psychrometer. With this instrument you will be able to measure the relative humidity of the air in your home at any time.

Examine the thermometers in your unit and note both the Celsius and Fahrenheit

readings. Cut off the cardboard backing of both your thermometers just below the lowest degree shown. Do this very carefully so that you will not accidentally break off the bulb. Seal the back and front surfaces and edges of the cardboard backing of the thermometer you plan to use for the wet-bulb thermometer with cellophane tape to water-seal it.

Obtain a fairly heavy piece of cardboard about 8½ x 11 inches in size. Measure two inches inward from each side along one of the 8½-inch edges and then mark points 1½ inches directly above these two points. Directly above these points measure another 1½ inches. Draw lines between the four points. Cut out this resuting 4½ x 1½-inch rectangular area (Fig. 1).

Mount the two thermometers about an inch apart at the center of the upper edge of the rectangular space, placing the wet-bulb thermometer to the right. Place both thermometers so that the bulbs project and are exposed to the air (Fig. 1).

Make a slit in the cardboard directly below the wet-bulb thermometer and measure off one-half inch along each side of the slit. Fold back the half-inch strips.

Obtain a small pill bottle or vial about one inch in diameter and not more than

2 inches tall. Secure it with tape in the one-inch opening (Fig. 1) you just made. The size of the slot can be adjusted by bending back more or less of the edge to suit the bottle you are using.

Punch holes on the cardboard backing about an inch from each edge and one-half inch below the top edge. Pass a string through the holes for hanging.

Paste your relative humidity table on the cardboard backing above the thermometers and below the holes so that you will be able to read the percentages directly as you observe the temperatures.

Fasten the wick to the bottom of the bulb of the thermometer on the right. Tie it securely above the bulb with a piece of thread. Fill the bottle with water at room temperature and insert the free end of the wick in the bottle. See that the wick around the bulb is thoroughly wet. Do not allow the mouth of the bottle to cover the bulb.

Hang your wet-and-dry-bulb hygrometer in a location where there is free access to air from all sides. Fan the wet-bulb thermometer until the temperature will go no lower and then take a reading from both thermometers.

If your hygrometer cannot be hung in a convenient spot, a prop can be easily

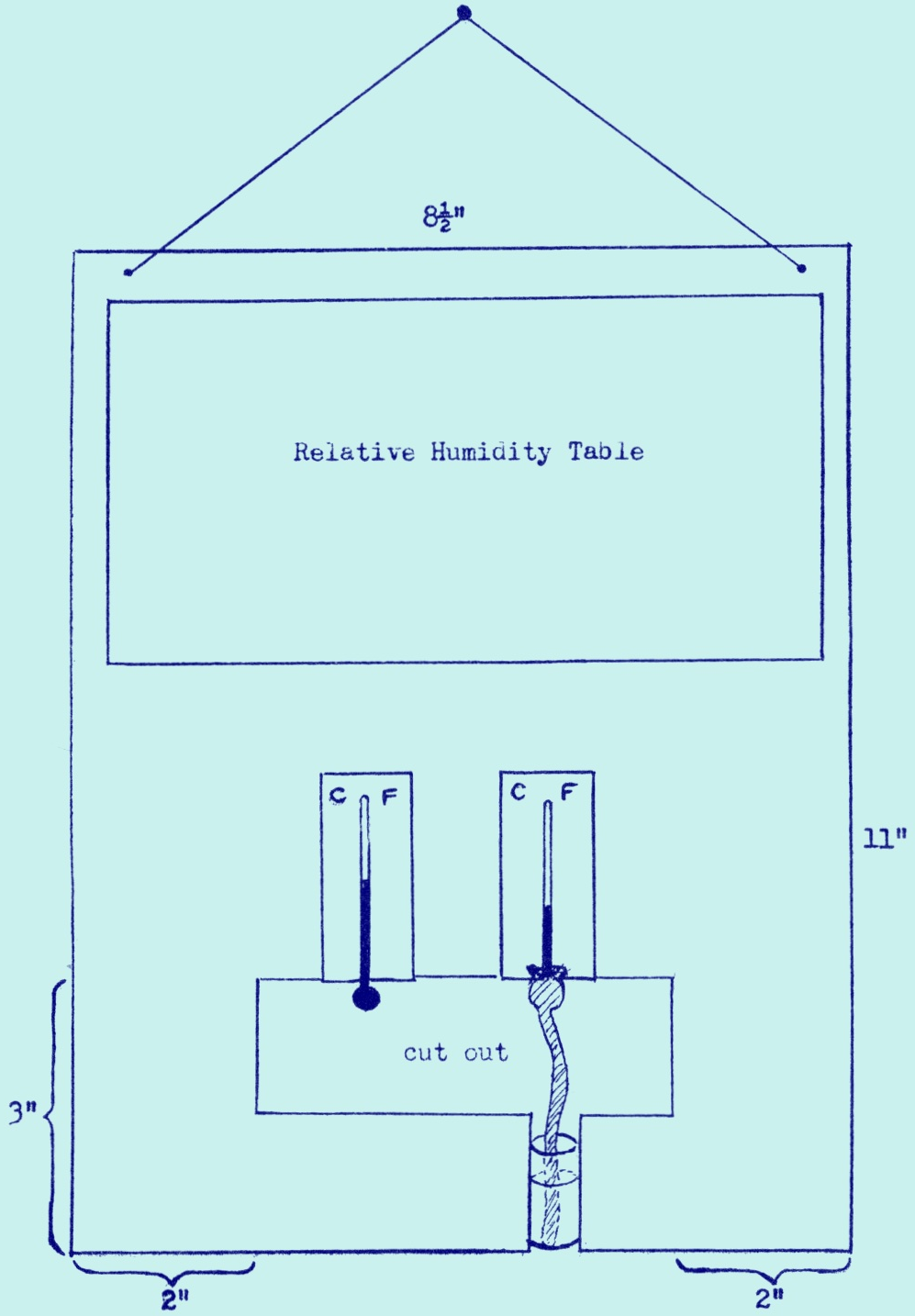


Fig. 1

made on the back so that the instrument will stand upright on a table or desk.

Subtract the wet-bulb reading from the dry-bulb reading and then find the relative humidity on the table. For example, if the air temperature, the dry-bulb temperature, is 60°F, and the difference between the wet-bulb and dry-bulb temperatures is 10°F, then the relative humidity is 48%.

Relative humidity may be expressed in equation form as

$$\text{R.H.} = \frac{\text{actual vapor content of atmosphere}}{\text{maximum possible vapor content}} \times 100$$

at a given temperature and pressure. However, the effect of pressure on the values is not significant and may be ignored for our purposes.

Thus, if at a certain temperature the water vapor content of the air is 20 grams per cubic meter of air and could contain a maximum of 40 grams, the relative humidity is 50%.

Experiment 2. In the winter when homes are heated, the relative humidity within the home is lower than in the actual atmosphere. With your wet-and-dry-bulb hygrometer, find the relative humidity inside your home and then outside the

home (unless temperatures are freezing) and compare the two results.

Listen to the weather report on the radio or television and check the relative humidity value you obtain with the official report. The relative humidity given by the weather announcer refers to outdoor conditions. Therefore, your observations, when checking against the official weather report, must be made outside during the winter. This would also be true in the summer if your home is air-conditioned. The air within a heated or cooled home will not show the true relative humidity of the atmosphere.

Cold air has less capacity to hold moisture than warm air. If the air in your home is heated, its capacity to hold moisture is increased. The evaporation rate of the moisture from the wet bulb is higher due to the drying effect of the heating system and to the higher temperature. The relative humidity is therefore less. To counteract this, heating systems are usually combined with a humidifier to add moisture to the air.

Experiment 3. Observe the relative humidity on five successive days. Is there much variation? Is the temperature difference between the two thermometers greater in dry weather than damp weath-

er? Why? Do your results coincide with the weather? Is the humidity higher on rainy days than on dry days?

Experiment 4. Take the relative humidity of various rooms in your home. Do they vary? Is the bathroom or kitchen more humid than other rooms in your home? Observe the relative humidity outdoors now and later on during spring, summer and fall. Record your readings and compare. What do you find?

DEW POINT

When the relative humidity is very high, fog may form, or it may rain. A little increase in moisture in the air or a slight drop in temperature can bring about such a change.

When you are out walking on a cold crisp day, your breath forms a white cloud, but when you return into the warmth of the house, this is no longer so. This is an example of how temperature effects humidity. The warmer the air, the more moisture it can hold.

The dew on the grass early in the cool morning of a summer day is also such an example.

The temperature at which the air becomes saturated and will take on no additional moisture is called the dew point.

Experiment 5. A simple experiment can be done to find the dew point of any atmosphere.

For this experiment borrow one of the thermometers from your hygrometer if you do not have a household thermometer handy. Obtain a glass of ice water and a glass of hot water, a thin aluminum or tin cup, or a thin metal can such as a small juice can from which the outside label has been removed.

Put a small amount of water of room temperature into the cup and insert the thermometer into the water. Slowly lower the temperature of the water by adding ice water to it. As you do this watch for the formation of dew on the outside of the cup. Stir the water so that the temperature is the same throughout. What is the temperature of the water when dew first forms on the cup? Note it down.

Now slowly add the warm water while continually wiping the dew from the outside of the cup. What is the lowest temperature at which the dew no longer forms? Take the average of these two readings and you will have the dew point.

Compare the dew point taken indoors and outdoors.

Experiment 6. Using the chart on page 13, you will be able to find the dew

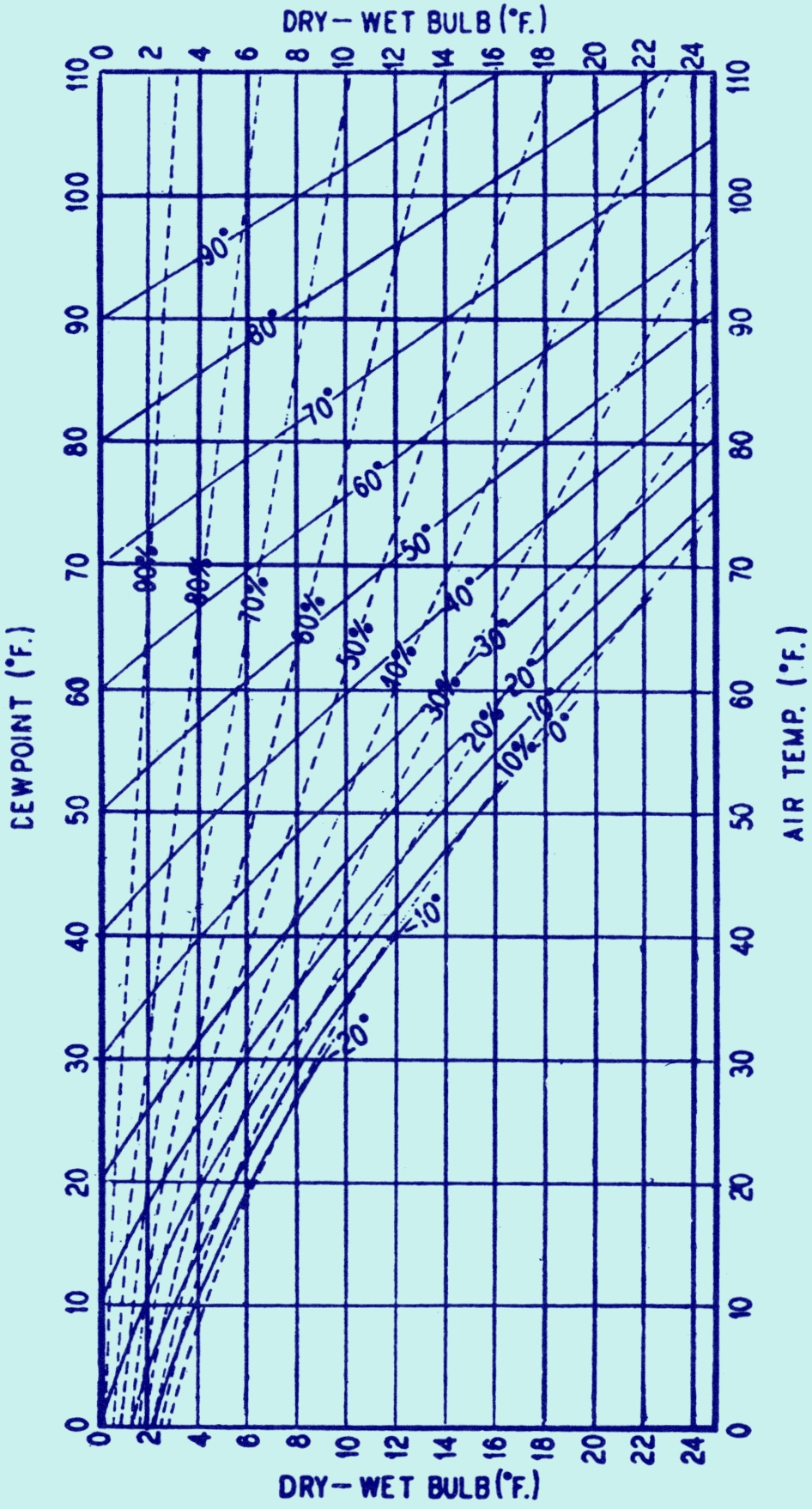
point by means of your hygrometer. This chart based on the U. S. Weather Bureau humidity tables was prepared by Harvard University's Blue Hill Meteorological Observatory.

Take wet-bulb and dry-bulb temperatures and note the difference between the two. Find the temperature shown by the dry-bulb thermometer across the top or bottom of the chart. Next find the number equal to the degrees difference between the readings of the thermometers on the right or left vertical readings. Note where the vertical and horizontal lines of these readings meet. The sloped line nearest the point where the two lines meet indicates the dew point. The dotted line nearest the point gives the relative humidity.

At air temperature 70 and a dry-minus-wet-bulb reading of six, for example, the dew point is 60 and the humidity about 70%.

How do the relative humidity values you observe by this method compare with those you have already obtained?

Experiment 7. The dew point if observed outdoors will help you judge the heights of the bases of clouds that are forming at this time. If the dew point is three degrees lower than the air temperature, the clouds will be forming at about


DRY – WET BULB (°F.)
0 2 4 6 8 10 12 14 16 18 20 22 24
DEWPOINT (°F.)
AIR TEMP. (°F.)
0 10 20 30 40 50 60 70 80 90 100 110
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
90%
80%
70%
60%
50%
40%
30%
20%
10%

700 feet. If the dew point is nine degrees under the air temperature, the clouds will be about 2,000 feet high.

The air temperature approaches the dew point at the rate of 4.5 degrees per 1,000 feet. Can you calculate from the dew point, the height of the clouds that are forming?

HAIR HYGROMETER

Human hair is extremely sensitive to changes in humidity, lengthening as humidity increases and shortening as the air becomes dry. Thus, scientists have devised a hair hygrometer from which relative humidity can be read directly.

Experiment 8. You can construct such a hygrometer and calibrate the scale using the wet-and-dry-bulb hygrometer you have constructed as a guide.

Obtain a strand of hair, about 8 to 10 inches long that has never been dyed and is not artificially waved. The change in length is best observed when the natural oil of the hair is removed. To remove the oils and fats from the hair immerse in a household solvent. Natural blond hair shows the greatest uniformity in change.

Take a piece of cardboard about 8½ x 11 inches in size. Make a crease across one of the narrower edges of the cardboard about one-half inch down so that the edge

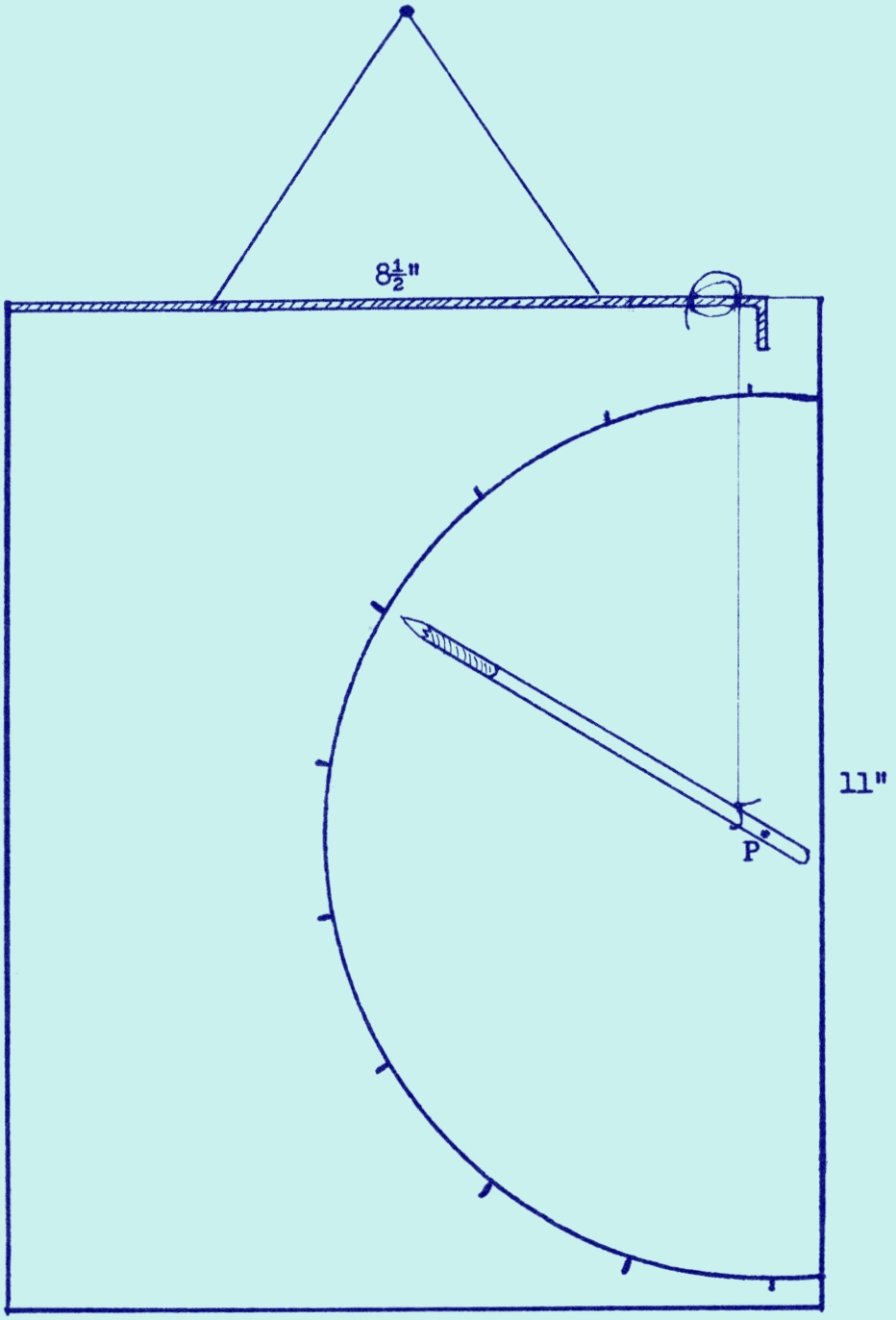


Fig. 2

stands up at right angles to the rest of the cardboard.

With a pair of scissors make a half-inch slit along the crease from the right hand edge. Bend the one-half-inch cut inward so that it produces a right-angle corner. Secure with cellophane tape.

About one-fourth inch to the left from the top edge of this corner, make a quarter-inch slit cutting down from the top edge and another similar slit ¼-inch further to the left. The hair will be passed through these slits and secured (Fig. 2).

Paste a sheet of white unlined paper on the cardboard beginning just below the crease at the top.

On the sheet 5½ inches down from the crease and ¾ inches in from the right-hand edge, mark a point P with a pencil. This will be the central point on which the pointer for the hygrometer will pivot.

Cut out from another sheet, two one-inch square pieces of cardboard. Glue the two pieces together and then glue them to the large cardboard just behind point P. The greater thickness thus created, will help keep the pin on which the pointer will turn straight and secure.

From the point end of an old pencil, cut off a piece about 1½ inches long and then whittle it down to fit into the Glassip

straw, making a sharp point on the lead. Insert the blunt end of this bit of pencil carefully into one end of the straw for about one inch. The pointed end will protrude about ½ inch. The piece of pencil provides the weight needed for the pointer and its fine point accuracy in making readings.

With a compass draw a half circle of about 4½-inch radius using point P as the center of the circle. A pin with a string and pencil attached can serve as a compass if necessary.

Pass a straight pin across the free end of the straw a quarter of an inch from the edge, and then through the center point P and the pieces of cardboard mounted on the back. Be sure the pin is horizontal as it passes through the cardboard. Push the pin through until its head just barely touches the straw.

Move the straw up and down to be sure it moves freely.

Tie the cleaned length of hair around the straw close to the pin. Pass the other end through the slits you have made at the upper edge of the cardboard and draw the hair up so that it is taut. Be sure the hair does not rub against the cardboard backing and is straight up and down.

If the air is very dry pull on the hair

so that the pointer is high up in the circle. If wet, allow it to come to a stop lower down on the circle. When the pointer has been properly adjusted secure the hair to the cardboard at the slits with tape. Mark this point on the arc you have drawn. Take the relative humidity reading calculated from your wet-and-dry-bulb hygrometer and note this down as the reading for this point.

Take two more readings on different days or in different rooms of your house, being sure both hygrometers are in the same room or place, and note down these points and relative humidity readings on your scale. By taking three random readings you will be able to calibrate your hair hygrometer and then use it to read the humidity directly.

When the air is damp, the hair will stretch and the pointer fall lower on the circle. When the air is dry, it will tighten and the pointer will rise.

Take readings from both hygrometers on various days and see how closely they match.

WEATHER PICTURE

Experiment 9. Examine your cobalt chloride or cobaltous chloride crystals. What color are they?

Cobalt chloride ($CoCl_2$) has the convenient property of turning blue when dry and pink when wet. The cobalt chloride in your unit has the chemical formula $CoCl_2 \cdot 6H_2O$, which means six molecules of water are attached to each molecule of $CoCl_2$. The crystals with the water molecules, called water of hydration, attached are pink. If your crystals are blue, it means the cobalt chloride has lost its water of hydration to the surrounding atmosphere.

The cobalt chloride in your unit was contributed by Mallinckrodt Chemical Works, St. Louis, Mo.

Since the cobalt chloride goes a long way, use only half of your sample now so that you will have some left if you wish to do additional experiments.

Obtain some cotton or a piece of white blotting paper. On a sheet of white paper, draw a picture of a dog, a little girl, house or tree, or any other simple subject. Cut from your picture a small section such as the dog's nose, the little girl's blouse, or the chimney on the house and trace just this area on the blotting paper. Mount the picture on a stiff backing placing the blotting paper or some cotton in the proper cut-out section.

To two parts of your cobalt chloride add one part regular table salt (NaCl)

and dissolve the mixture in a teaspoon of water. The solution may be further diluted if desired. The colors may not be as strong but will be just as effective in showing humidity.

After the crystals have been completely dissolved, with a small brush paint the blotting paper or cotton section with the cobalt chloride solution. The painted part will be a bright pink. Allow to dry. Even after drying it may remain pink if the humidity of the room is high, but with less dampness it will gradually turn lavender and then blue if completely dehydrated. To speed up drying, since you may wish to observe the color change, place the picture on a radiator or in a warm oven.

To turn the spot pink again, place the picture in a humid area such as in the bathroom or laundry. The change will be almost immediate and quite spectacular.

Your weather picture if hung near a window will be most exposed to hygrometric changes in the atmosphere.

Experiment 10. Note the changes in color that occur in your humidity indicator and check them against the wet-and-dry-bulb and hair hygrometers. By this means you will be able to approximate the relative humidity by color, although it, of course, would not be a precise indicator.

Experiment 11. For checking humidity by color outdoors, make a little figure out of blotting paper small enough to fit inside a medicine bottle or vial. Wet the figure with the cobalt chloride solution. Invert a small glass or vial over the figure after it dries and secure it in the vial with transparent tape or glue. Hang the inverted vial with its mouth unsealed outside near a window and you will be able each day to observe at a glance, whether the weather is dry or damp.

The change in color is typical of cobalt chloride. In the dry or anhydrous state the blue color is prominent because the cobaltous chloride molecule vibrates as a whole to absorb the red and green parts of the spectrum. In the wet state, the color comes from the cobaltous ion due to the way the cobalt and chloride ions are separated by the molecules of water which have joined the structure.

The chemical changes from pink to blue at 20% relative humidity, to lavender at approximately 30% relative humidity and remains pink at 40% relative humidity.

The table salt does not have an effect on the cobalt chloride. It is combined with the cobalt chloride since sodium chloride is hydroscopic and absorbs moisture readily from the air making the indicator more

effective.

You can use the cobalt chloride for an entirely different, but amusing purpose. The chemical serves as "magic ink." Write a letter to one of your friends using the cobalt chloride solution. The liquid will not show up when you write, but will appear dark blue when a hot iron is passed over it.

RAIN GAUGE

You may wish to know the quantity of rainfall during a storm. The weather report usually indicates the number of inches of rainfall when a storm has occurred.

Experiment 12. You can make a simple rain gauge using a large fruit can or some other metal container that has perfectly vertical sides and a flat bottom. Cut the can off evently around the top and place it outside in an open area where it will catch the rain no matter from which direction the wind blows. Insert the can part way into the ground so that it is secure and will not overturn by the force of the wind or rain.

Use an ordinary ruler to measure the depth of the water in the can. You can check the rainfall of any particular storm and compare your findings with the

weatherman's figures. If you wish to measure the rainfall of a particular week or month, jot your findings down every 24 hours and empty your can of any water after each reading. By dividing the number of days into the total number of inches of rain measured you will get the average rainfall per week or month as desired. You may be surprised at how little water is collected during even bad storms.

Professional weather observers, of course, use much more elaborate instruments than this to obtain accurate rainfall measurements, but your instrument will give fairly close results.

A useful booklet containing detailed relative humidity tables, "Psychrometric tables for obtaining the vapor pressure, relative humidity and temperature of the dew point," by C. F. Marvin, may be purchased from the U. S. Government Printing Office, Washington, D. C.

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RELATIVE HUMIDITY
(percent)

Difference between wet- and dry-bulb temperatures (t - t')

Air temp. °F	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
40	92	83	75	68	60	52	45	37	29	22	15	7	0												
42	92	85	77	69	62	55	47	40	33	26	19	12	5	0											
44	93	85	78	71	63	56	49	43	36	30	23	16	10	4	0										
46	93	86	79	72	65	58	52	45	39	32	26	20	14	8	2										
48	93	86	79	73	66	60	54	47	41	35	29	23	18	12	7	1									
50	93	87	80	74	67	61	55	49	43	38	32	27	21	16	10	5	0								
52	94	87	81	75	69	63	57	51	46	40	35	29	24	19	14	9	4								
54	94	88	82	76	70	64	59	53	48	42	37	32	27	22	17	12	8	3							
56	94	88	82	76	71	65	60	55	50	44	39	34	30	25	20	16	11	7	2						
58	94	88	83	77	72	66	61	56	51	46	41	37	32	27	23	18	14	10	6	1					
60	94	89	83	78	73	68	63	58	53	48	43	39	34	30	26	21	17	13	9	5	1				
62	94	89	84	79	74	69	64	59	54	50	45	41	36	32	28	24	20	16	12	8	4	1			
64	95	90	84	79	74	70	65	60	56	51	47	43	38	34	30	26	22	18	15	11	7	4	0		
66	95	90	85	80	75	71	66	61	57	53	48	44	40	36	32	29	25	21	17	14	10	7	3	0	
68	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	31	27	23	20	16	13	10	6	3	
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76	96	91	87	82	78	74	70	66	62	59	55	51	48	44	41	38	34	31	28	25	22	19	16	13	11
78	96	91	87	83	79	75	71	67	63	60	56	53	49	46	43	39	36	33	30	27	24	21	18	16	13
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35	32	29	26	23	20	18	15
82	96	92	88	84	80	76	72	69	65	61	58	55	51	48	45	42	39	36	33	30	28	25	22	20	17
84	96	92	88	84	80	76	73	69	66	62	59	56	52	49	46	43	40	37	35	32	29	26	24	21	19
86	96	92	88	84	81	77	73	70	66	63	60	57	53	50	47	44	42	39	36	33	31	28	26	23	21
88	96	92	88	85	81	77	74	70	67	64	61	57	54	51	48	46	43	40	37	35	32	30	27	25	22
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41	39	36	34	31	29	26	24
92	96	92	89	85	82	78	75	72	68	65	62	59	56	53	50	48	45	42	40	37	35	32	30	28	25
94	96	93	89	85	82	79	75	72	69	66	63	60	57	54	51	49	46	43	41	38	36	33	31	29	27
96	96	93	89	86	82	79	76	73	69	66	63	61	58	55	52	50	47	44	42	39	37	35	32	30	28
98	96	93	89	86	83	79	76	73	70	67	64	61	58	56	53	50	48	45	43	40	38	36	34	32	29

t = dry-bulb temperature t' = wet-bulb temperature